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Air Force Space Command

SPACE AND MISSILE SYSTEMS CENTER STANDARD

TEST REQUIREMENTS FOR GROUND SYSTEMS

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FOREWORD

1. This standard defines the Government's requirements and expectations for contractor performance in defense system acquisitions and technology developments.

2. This new-issue SMC standard comprises the text of The Aerospace Corporation report number TR-2013-00215, entitled *Test Requirements for Ground Systems*.

3. Beneficial comments (recommendations, changes, additions, deletions, etc.) and any pertinent data that may be of use in improving this standard should be forwarded to the following addressee using the Standardization Document Improvement Proposal appearing at the end of this document or by letter:

Division Chief, SMC/ENE
SPACE AND MISSILE SYSTEMS CENTER
Air Force Space Command
483 N. Aviation Blvd.
El Segundo, CA 90245

4. This standard has been approved for use on all Space and Missile Systems Center/Air Force Program Executive Office - Space development, acquisition, and sustainment contracts.

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1. Scope

1.1 Purpose

This standard establishes the requirements for functional, performance, and environmental testing of ground systems, subsystems, and units that support launch and operation of launch vehicles, upper-stage vehicles, and space vehicles. This standard establishes requirements to test the system in all configurations and conditions of mission operations. In addition, a uniform set of definitions of related terms is established.

1.2 Application

This standard is applicable to the procurement of ground systems hardware and software for space systems as a compliance document for the establishment of a minimum set of test requirements. The standard applies to organizations developing any portion of the ground system.

The test requirements in this standard are applicable to the design, development, and integration of new, reused, or modified software and hardware in ground systems that provide command and control, mission management, mission data processing, and common services (e.g., data storage, networks, and other shared functions) for space vehicles. They also apply to training systems and simulators used for training operators and maintainers of ground systems.

This standard applies to systems installed in fixed and non-fixed environments that directly support launch and operation of space systems. This standard does not apply to ground support equipment used for transport, handling, and test support of space and launch vehicles. ,

The term, ground system, is used in this standard for the top level item to be tested. Terminology used in a specific development will likely differ, particularly large or complex procurements. For example, large space program procurements frequently use the “system” designation for all components developed, to include a space segment, a ground segment, a launch segment, and a user segment. There also may be further subdivision of a ground segment such as two or more ground elements.

The definition for “Test Item Levels” in section 3 lists the test levels used in this standard, which should be translated and tailored for the levels and terms of a specific program.

The test requirements herein focus on design verification and the elimination of latent defects, not evaluation of workmanship issues, to help ensure a high level of confidence in achieving successful space missions.

1.3 Test Categories

The test requirements discussed herein are categorized as follows:

1.3.1 Developmental Tests

Developmental tests are planned and performed by the developers to verify correct implementation and compliance with specifications, provide evidence for acceptance of developed systems, and collect data to certify readiness for operational testing. Types of developmental tests include:

1. **Development tests.** Tests conducted during development of hardware and software items to confirm design adequacy and verify that hardware manufacture and assembly, and software implementation perform as designed.
2. **Qualification tests.** Tests performed to demonstrate that hardware, software, or integrated items meet specified requirements.
3. **Acceptance tests.** Formal tests required for contractual acceptance of a ground system.
4. **Integrated system tests.** Tests performed with the new ground system integrated with other program elements or segments under development, and with existing installed systems, to verify correct interface implementation and correct end-to-end operation of the integrated systems.

1.3.2 Operational Tests

Operational tests are conducted by the procuring activity or a designated test organization, in coordination with the operations organization. Test support is provided by developers as designated in the statement of work (SOW). These tests are conducted to test and evaluate the capability of the ground system to meet the operational requirements. Operational tests may be combined with developmental tests when objectives can be satisfied concurrently.

1.4 Test Requirements

Environments other than those specified in section 5.1.1.2 of this standard can be sufficiently stressful as to warrant special analysis and testing. These include environments such as combat conditions, or nuclear and electromagnetic radiation.

2. Applicable Documents

2.1 General

The documents listed in this section are specified as compliance documents in Sections 3, 4, or 5 of this standard.

2.2 Government Documents

2.2.1 Specifications, Standards, and Handbooks

The following specifications, standards, and handbooks form a part of this document to the extent specified herein. The revisions of these documents to be used are those specified in the solicitation or contract. If revision is not specified by contract or other agreement, the version current at initiation at initiation of the development is to be used.

DEPARTMENT OF DEFENSE STANDARDS

[1]	MIL-STD-461	Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment
[2]	MIL-STD-810	Environmental Engineering Considerations and Laboratory Tests
[3]	MIL-STD-188-125-1	High-Altitude Electromagnetic Pulse (HEMP) Protection for Ground-Based C41 Facilities Performing Critical, Time-Urgent Missions, Part 1, Fixed Facilities
[4]	MIL-STD-188-125-2	High-Altitude Electromagnetic Pulse (HEMP) Protection for Ground-Based C41 Facilities Performing Critical, Time-Urgent Missions, Part 2, Transportable Systems

2.2.2 Other Government Documents, Drawings, and Publications

The following other government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the revision of these documents is that specified in the solicitation or contract. If revision is not specified by contract or other agreement, the version current at initiation of the development is to be used.

CODE OF FEDERAL REGULATIONS

[5]	Federal Code of Regulations FCC Part 15	Federal Code of Regulations, Title 47: Telecommunication, Part 15–Radio Frequency Devices

2.3 Non-government Publications

The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the revisions of these documents are those cited in the solicitation or contract. If revision is not specified by contract or other agreement, the version current at initiation of the development is to be used.

THE AEROSPACE CORPORATION

[6]	TOR-2004(3909)-3537B	Software Development Standard for Space Systems, March 11, 2005 [Issued also as SMC-S-012 (2008), Software Development for Space Systems]

INSTITUTE OF ELECTRICAL AND ELECTRONIC ENGINEERS (IEEE)

[7]	IEEE Standard C95	IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3kHz to 300 GHz
[8]	IEEE Standard 1100	Recommended Practices for Powering and Grounding Electronic Equipment

2.4 Order of Precedence

In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. Definitions

Acceptance: The action taken by the acquirer's designated representative by which the acquirer assumes ownership of products that signify partial or complete performance of a contract.

Acceptance test: The required formal tests conducted to demonstrate acceptability of an item for delivery. The tests are designed to demonstrate performance to specified requirements and to act as quality control screens to detect deficiencies of workmanship, material, and quality.

Analysis, verification by: Verification of a specification requirement by use of mathematical or statistical methods, modeling and simulation using data from software and hardware engineering documents produced during product development or provided by COTS vendors, from prototypes, or from lower-level tests. Note: Analysis that must be performed on the data collected during the demonstration or test methods is an integral part of those methods and should not be confused with the analysis method described here.

Bug (software): Common and traditional slang for a defect in software syntax or logic that causes anomalous behavior of the system.

Build (software): Can have two meanings: (1) the version of software that meets a subset of the requirements allocated to the completed software system, or (2) the period of time during which the version with the subset of requirements is developed.

Commercial Off the Shelf (COTS): Commercial items that require no unique government modifications or maintenance over the lifecycle of the product to meet the needs of the procuring agency. A COTS item (hardware, software, or both) is produced and made commercially available or placed in stock by a vendor prior to the vendor receiving orders or contracts for sale of the item. The vendor may produce the item to either commercial, military, or federal specifications or descriptions. COTS includes items stocked by distributors for which government contracts may be received.

Component: A generic designation for a part of the system (not used to describe a level of software hierarchy, since that use is obsolete, nor as a synonym for a hardware part).

Debug: To detect, locate, and correct faults in a computer program.

Defect: A flaw in a system, hardware, or software item. The cause of a failure. That which is corrected to correct a failure.

Demonstration, verification by: Verification of a specification requirement by observing functional operation of the system or part of the system without the use of instrumentation or special test equipment beyond that inherently provided in the system being verified.

Department of Defense (DOD) standard: A standard used to satisfy primarily multiple, military-unique applications. There are five types of DOD standards: interface, design criteria, manufacturing process, standard practices, and test method standards.

Dependability: An umbrella term for six system attributes:[1]

- Availability: readiness for correct service
- Reliability: continuity of correct service
- Safety: absence of catastrophic consequences on the user(s) and the environment
- Integrity: absence of improper system alterations
- Maintainability: ability to undergo modifications and repairs
- Confidentiality: absence of unauthorized disclosure of information

Developer: The groups or organizations performing the development of the ground system, including prime contractor, subcontractors, team members, government development staff, or associated agencies' development staff. A team member is any internal or external organization that develops, tests, or supports work for the ground system by an agreement (formal or informal) with any other developer.

Discrepancy (test): A functional or structural anomaly or failure which indicates a possible deviation from specification requirements for the test item. A test discrepancy may be a momentary, nonrepeatable, or permanent failure to respond in the predicted manner to a specified combination of test environment and functional test stimuli. Test discrepancies may be due to a failure of the test item or to some other cause, such as the test setup, test instrumentation, supplied power, or test procedures.

Discrepancy Report (DR): Description of the discrepant behavior and effect on the system component being tested. Report may also include information for managing and analyzing defects and testing, such as proposed correction, due date, assignee, completion date, source (requirements, design, implementation, etc.) or cause of the discrepancy. Also called problem report, deficiency report, and other similar terms.

Failure: The inability of a system or component to perform its functions as specified or within specified performance parameters. Behavior of a system or system component that deviates from specified requirements. A test step not passed.

Fault: See Defect.

Firmware: Firmware is a combination of a hardware device and computer instructions or computer data that reside as read-only software on the hardware device. The software cannot be readily modified under program control.

Functional Configuration Audit (FCA): Verifies that all item or subsystem requirements established in the functional and allocated baselines, specifications, and test plans have been verified successfully, and corrective action has been initiated, as necessary.

Inspection, verification by: Verification of a specification requirement by examination of the product using the human senses or by simple, nonprecision measurements or examination of software and hardware engineering documents produced during product development or provided by COTS vendors.

[1] A. Avizienis, J.C. Laprie, B. Randell, and C. Landwehr, "Basic Concepts and Taxonomy of Dependable and Secure Computing," *IEEE Transactions on Dependable and Secure Computing*, Vol. 1, No. 1, pp. 11-33, January-March 2004.

Integration: Connection and/or interoperation of newly developed or modified software or hardware test items into configurations that allow test of functions and operations of the combined items. Also connection and/or interoperation of the ground system with other items, existing or in development, e.g., spacecraft or other ground systems.

Non-developmental Item (NDI): An NDI is any previously developed item of supply used exclusively for government purposes by a federal agency, a state or local government, or a foreign government with which the United States has a mutual defense cooperation agreement; any item described above that requires only minor modifications or modifications of the type customarily available in the commercial marketplace in order to meet the requirements of the procuring department or agency.

Non-fixed Equipment: Equipment that is transportable, mobile, or portable. Transportable equipment is deployable and redeployable but not self-propelled, requiring separate vehicle(s) for transport. Mobile equipment is self-propelled and capable of mission operations while moving or shortly after stopping. Portable equipment is capable of being carried by one or more persons.

Part: A part is a single piece, or two or more pieces joined together, which are not normally subject to disassembly without destruction or impairment of the design use. Some examples are resistors, transistors, integrated circuits, relays, capacitors, gears, screws, and mounting brackets.

Physical Configuration Audit (PCA): Physical examination of the actual configuration of the item produced. It verifies that the design and product documentation specified in the contract matches the as-built item and that all documentation/deliverables to the operational site are present, complete, and accurate.

Procuring Activity: The procuring activity is the government office or agency with primary responsibility for developing and acquiring the system, subsystem, equipment, computer software, or engineering services addressed in this document.

Problem Report: See Discrepancy Report.

Regression Test: A test performed after system changes have been made to verify that the changes did not inadvertently introduce failures to system functions that were working properly prior to the changes.

Requirements Verification Traceability Matrix (RVTM): See Verification Cross-reference Matrix (VCRM).

Software Development Environment: The computers and software development tools used to conduct coding and unit testing of a software item. The computers and support software may not be identical to the target hardware and support software. See Software Integration and Test Environment.

Software Development File (SDF): A repository for material pertinent to the development of a particular body of software. Contents typically include (either directly or by reference) considerations, rationale, and constraints related to requirements analysis, design, and implementation; developer internal test information; and schedules and status information.

Software Integration and Test Environment: The developer-controlled and developer-maintained configuration of computer and communications hardware, test and measurement software, and equipment used to perform integration and qualification testing of software.

Software Item: An aggregation of software that satisfies an end-use function and is designated for purposes of specification, interfacing, qualification testing, configuration management, or other purposes. A software item comprises one or more software units. A software item was sometimes previously called a computer software configuration item. See also Software Subsystem.

Specification: A document used in development and procurement that describes the technical requirements for items, materials, and services. Specifications may be unique to a specific program (program peculiar) or they may be common to several applications (general in nature).

Subassembly: The term subassembly denotes two or more parts joined together to form a stockable unit which is capable of disassembly or part replacement. Examples are a printed circuit board with parts mounted, or a gear train.

Subsystem, Hardware: A subsystem is an assembly of two or more components, including the supporting structure to which they are mounted, and any interconnecting cables or tubing. A subsystem is composed of functionally related components that perform one or more prescribed functions.

Subsystem, Software: Synonymous with, or instead of, software item in some programs. The specification level consisting of software requirements.

System of Systems: A set or arrangement of interdependent systems that are related or connected to provide a given capability. The loss of any part of the system will significantly degrade the performance or capabilities of the whole.

System Verification Review (SVR): A multidisciplinary technical review to ensure the system is ready to proceed into low-rate initial production and full-rate production within cost (program budget), schedule (program schedule), risk, and other system constraints. Generally this review provides an audit trail from the critical design review.

Test: Activities conducted to obtain data to verify that an implementation is as designed, that specification requirements are satisfied, and to identify defects and deficiencies for corrective action. Tests that verify these requirements can use verification methods described in the definitions for: Analysis, verification by; Demonstration, analysis by; Inspection, analysis by; and Test, verification by. The narrower use of the term ‘test’ is one method to verify a requirement, as described in the definition for Test, Verification by.

Test Documentation File: A repository for material pertinent to the test of a unit, subsystem, or other component of a ground system. Contents typically include (either directly or by reference) test plans, procedures, data, results, reports, and schedules and status information. Would also include analysis of anomalies, and root cause of anomalies, rationale for retest, and regression test.

Test Environment: Test environments for hardware consist of the facility housing the equipment under test, necessary fixtures or special handling equipment, plus the required test instrumentation. Test environments for software consist of the computing hardware running the software, test drivers, databases and simulators, data collection and analysis software, test execution scripts, or automated test software.

Test Item Levels: The levels used in this document, from the simplest to the most complex, are:

Hardware	Software
Part	Unit
Subassembly	Software Item
Unit	Subsystem (alternate for software item or not used in some systems)
Subsystem	System
System	

Additional levels such as "segment" and "element" are used in large ground "system-of-systems configurations." These levels will be defined by the procuring activity.

Test Method Standard: A standard that specifies procedures or criteria for measuring, identifying, or evaluating qualities, characteristics, performance, and properties of a product or process.

Test Readiness Review (TRR): A multidisciplinary technical review and process assessment to ensure that a subsystem or system is ready to proceed into formal test. The TRR assesses test objectives, test methods and procedures, scope of tests, and safety, and confirms that required test resources have been properly identified and coordinated to support planned tests.

Test, verification by: Verification of a specification requirement by exercising or operating the system or a part of the system and performing measurements using hardware or software instrumentation or special test equipment that is not a part of the system being verified.

Unit, Hardware: A separately testable component of a hardware design that is part of a subsystem.

Unit, Software: An element in the design of a software item; for example, a major subdivision of a software item, a component of that subdivision, a class, object, module, function, routine or database. Software units in the design may or may not have a one-to-one relationship with the code and data entities (routines, procedures, databases, data files, etc.) that implement them or with the computer files containing those entities. A software unit was sometimes previously called a computer software unit.

Validation: Confirmation that the product or service, as provided (or as will be provided), will fulfill its intended use. In other words, validation ensures that "you built the right thing."[2]

Verification: Confirmation that work products properly reflect the requirements specified for them. In other words, verification ensures that "you built it right."[2]

Verification Cross-reference Matrix (VCRM): Section of each specification or a separate document that lists, for each requirement, the requirement identifier and the verification method for the requirement—inspection, analysis, demonstration, or test. Called Requirements Verification Traceability Matrix (RVTM) on some programs.

[2] M.B. Chrissis, M. Konrad, and S. Shrum, *CMMI® for Development, Guidelines for Process Integration and Product Improvement*, Addison-Wesley, NJ, 2011, p. 603.

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4. General Requirements

4.1 Test Requirements

This standard establishes a minimum set of test requirements to be included as part of a complete test program. The test strategy is a process of development, integration, and qualification test at unit, subsystem, and system level to provide the highest probability of meeting specification requirements reliably under all operational conditions. The specific test requirements applicable at each level of test are presented in Section 5.

4.2 Testing Strategy

The complete test program for ground systems consists of developmental tests and operational tests. A satisfactory test program requires the completion of specific test objectives in a specified sequence. Ground systems that support space and launch vehicles are usually developed iteratively in a sequence of developments (e.g., builds, spirals, increments), each with defined tests. In many cases, ground system development activities consist of modifications and integration of updates into existing ground sites and systems. As such, the testing strategy may be streamlined with a goal toward efficiency; however, the strategy still needs to ensure thoroughness of the testing it prescribes and be acceptable to the procuring activity. The overall test program encompasses the testing of progressively more integrated ground system hardware and software. Small systems may not use an iterative development strategy and would be tested as a complete system. The phases of executing this test strategy are illustrated in Figure 1.

Design adequacy and correct implementation should be demonstrated in development tests prior to formal qualification testing. Test plans for requirements verification follow a bottom up test philosophy illustrated in Figure 2. That is, the requirements and hardware/software functions are verified at the lowest level where test configuration and environmental conditions constitute a valid test.

Tests must be performed to confirm that specification requirements are satisfied in all configurations and conditions that will be encountered during the mission. Test requirements will be derived from mission analysis and analysis of potential mission-critical failures. These tests can be integrated with other tests but may have to be performed as unique tests to provide required test conditions, stresses, and timelines with the goal of exposing mission operations flaws as early as possible.

This strategy of requirements verification through multilevel tests depends on accurate identification and tracking of test configurations for each test and retest through all the test levels. Test configuration identification, traceability of lower level tests, and traceability of requirements to tests shall be documented and maintained by the developer.

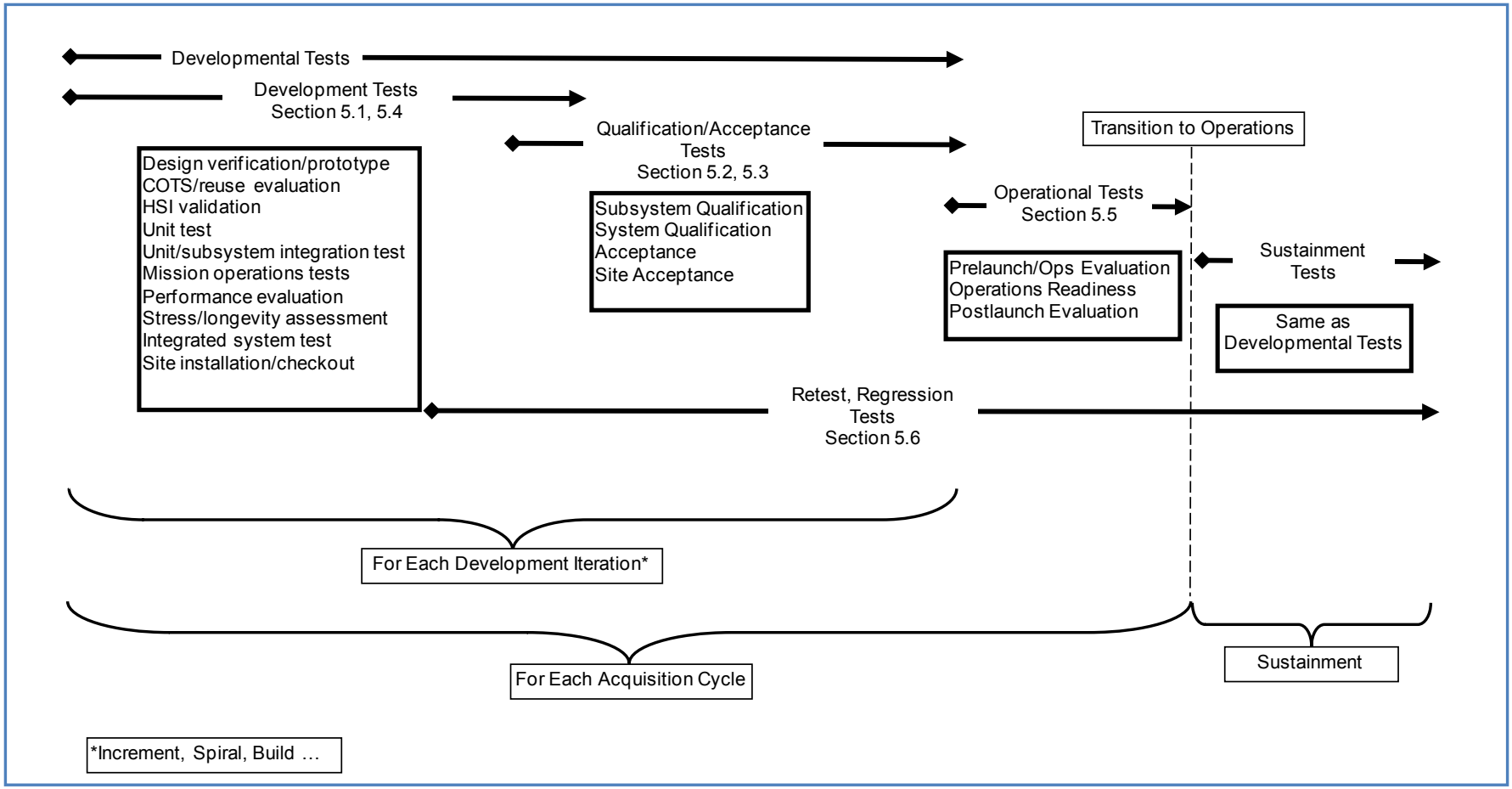

Figure 1. Ground system test phases.

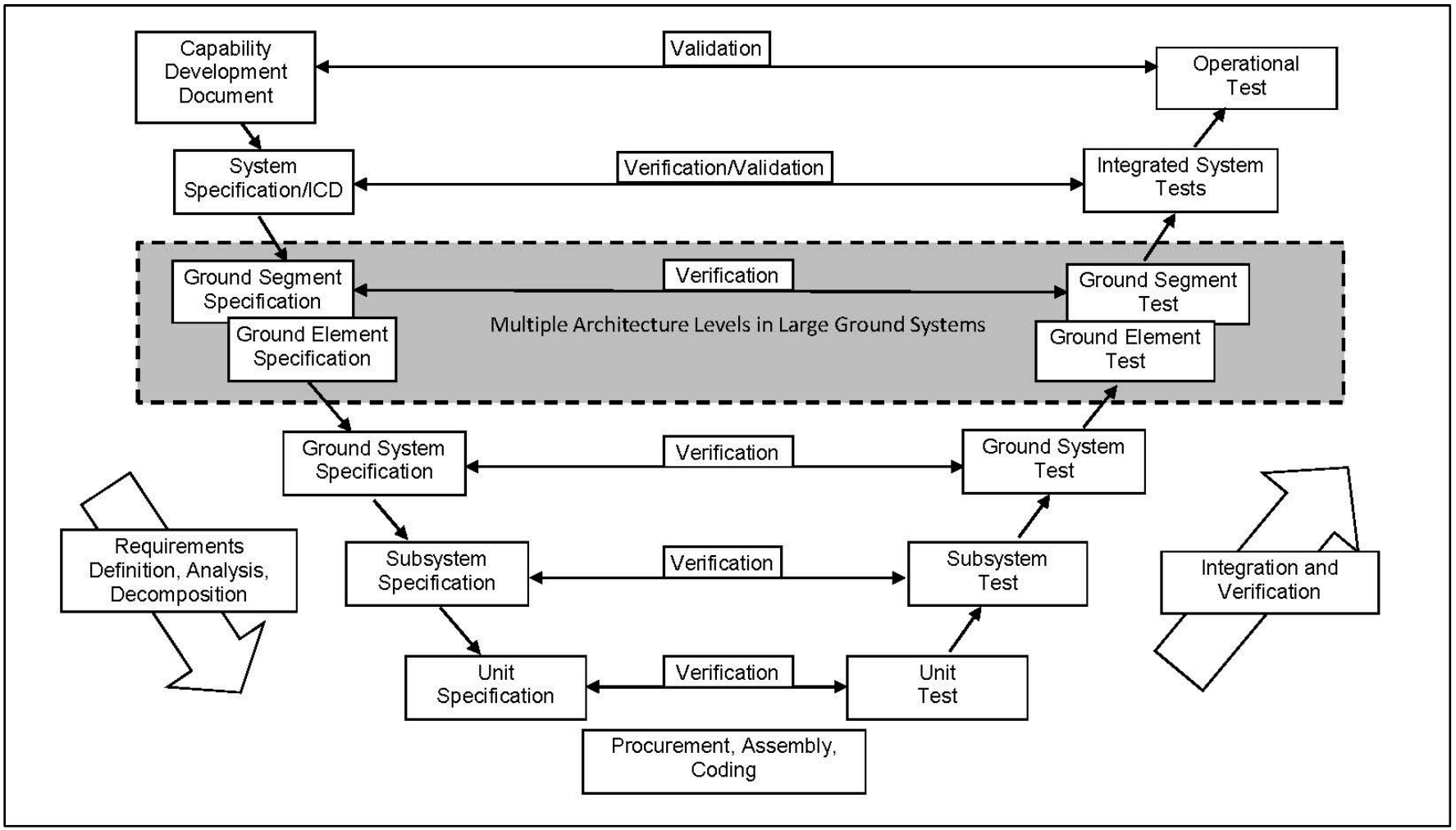

Figure 2. Requirements test diagram.

4.2.1 Developmental Tests

Developmental test and evaluation (DT&E) shall be conducted to assess the adequacy of ground system designs, verify correct implementation of designs in hardware and software items, and verify compliance with requirements as the system will be used in operation during the mission.

Software, developed or modified, shall be tested in accordance with the software test requirements of this standard. Unmodified commercial vendor software embedded in hardware components shall be tested with the host hardware in accordance with the hardware test requirements of this standard.

1. **Development Tests.** Tests during design and development shall be conducted to identify problems early in the design evolution, assembly, and development so that any required corrective actions can be completed prior to starting formal qualification testing. Tests shall be conducted on software or representative hardware articles to characterize engineering parameters, gather data, choose a design approach, verify correct implementation of designs, verify interface implementation, and verify correct operation of integrated components and subsystems in all configurations and conditions of mission operations. Detailed requirements for development tests are given in Section 5.1.
2. **Qualification Tests.** Qualification tests shall be conducted to verify that an item complies with the allocated requirements for the item. Qualification tests shall be conducted for each specification level and shall include COTS, NDI and government furnished property (GFP) items that are allocated program requirements. Items that are similar or identical may be qualified by analysis. Ground hardware items may be deemed qualified by similarity if analyses show that a similar unit has been designed and tested to the same or more stressing environmental and life performance requirements as specified. In this case, relevant documentation shall prove that the similarity and testing equivalency requirements of the procuring activity have been satisfied. Detailed requirements for qualification tests are given in Section 5.2.
3. **Acceptance Tests.** Acceptance tests shall be conducted to demonstrate that each contract deliverable item meets specification requirements and to identify any workmanship flaws or errors in manufacturing and assembly. Selected qualification tests performed by the developer may be designated as acceptance tests by the procuring activity, but acceptance tests may also be unique tests developed and performed by a separate agency or tester, e.g., independent test organization, user, security accreditation agency. Successful completion of the acceptance tests allows the authorized representative of the procuring activity to accept the ground system in partial or complete performance of a contract. Detailed requirements for acceptance tests are given in Section 5.3.
4. **Integrated System Tests.** Integrated system tests shall be performed to exercise, the total system, integrated with interfacing systems. Unless an exception is approved by the procuring activity, integrated system tests shall be performed on the integrated hardware and software items installed in an operational system with connection to actual interfaces, conducted at the target site with the support of the operational personnel. The objective of the tests is to ensure that the products, which may be from multiple developers, function correctly when integrated, that interfaces are verified, and that all system-level requirements or specifications are met. In addition, end-to-end tests that exercise the system in all configurations and conditions of mission operations shall be performed. Detailed requirements for integrated system tests are given in Section 5.4.

4.2.2 Operational Tests

Operational test and evaluation (OT&E) is performed by the procuring activity or a designated agency in coordination with the operating organization to appraise a system's operational effectiveness and suitability of new items, modifications, or installations (hardware, software, or both) and provides information on tactics, doctrine, organization, and personnel requirements in the operational environment. Operational tests may be combined with developmental tests when objectives can be satisfied concurrently, as designated by the procuring activity. Support to operational testing is provided by developers as designated in the contract statement of work (SOW). Developers collaborate with the procuring activity test team and independent test groups to conduct test planning, coordinate and align DT&E and OT&E objectives, and identify potential for combined developmental and operational tests. Detailed requirements for operational tests are given in Section 5.5.

4.2.3 Retest and Regression Test

Retesting shall be performed if a test discrepancy or test item failure occurs while performing any of the required testing. Following correction of the problem identified by the failure analysis, a retest of the failed test case and related areas identified by analysis of the implemented fix shall be performed. When analysis shows previous tests have been invalidated by the failure, those tests shall be repeated. Regression testing of software shall be performed after any modification to previously tested software and after each installation of software in a new environment or at a new site. Detailed requirements for retest and regression testing are given in Section 5.6.

4.3 Test Planning and Preparation

The test plans, descriptions, and procedures provide the framework for identifying and interrelating all of the individual tests and test procedures needed.

Test planning and preparation starts with requirements analysis, then continues in each program phase to ensure that testing is considered in developing requirements and designs and that test plans and procedures completely test the designs. The goal is to create:

- Requirements that are unambiguous, complete, and testable
- Product designs that include provision for efficient test, e.g., start/restart modes, test data injection, built-in test equipment (BITE), and test software
- Product designs that include provisions for capture of test data, system states, and test results

Planning for test data and simulations shall ensure that:

- Test data and simulators fully cover the extent of operational extremes in sufficient quantity and rates to test worst-case system loads and responses
- Simulators, simulations, models, and test tools to be used have been validated to ensure that the results produced and degree of fidelity are adequate for the intended use in the test program

The developer shall collaborate with integrated test teams established with other stakeholders to ensure that the combined test plans and procedures provide results and data that will meet the test and evaluation needs of the developer, procuring activity, users, and operators.

Note: Ground systems for space programs require multilevel test plans describing the hierarchical test program, generally consisting of top-level plans for the overall ground system and subordinate plans

for each element of the system, unit test, qualification tests, integration tests, acceptance plan, etc. The test plans describe implementation of the test phases and levels illustrated in Figures 1 and 2. In addition, ground software is usually developed using incremental approaches with multiple software builds tested separately, requiring test plans that describe the incremental tests and the interrelationships that satisfy the overall test objectives for the ground system. The test plans on large programs may be phased over time, with details completed to be available at multiple acquisition milestones.

4.3.1 Test Plans

The test plans shall provide a general description of each test planned and the conditions of the tests. The test plans shall be based upon a function-by-function mission analysis and any specified testing requirements. Tests shall be planned and executed to fulfill test objectives from development through operations to the maximum extent possible. Test objectives shall be planned to verify compliance with the design and specified requirements of the items involved, including interfaces. Software test plans shall comply with the Software Development Standard for Space Systems [10].

Test plans shall describe how the aggregate tests confirm that the ground system performs all requirements using realistic operational configurations, conditions, and timelines. The plans shall also describe and provide justification for any exceptions to this test requirement with a description of risk mitigation for the exceptions.

Test plans shall include or refer to an acceptance plan that defines the acceptance criteria, the acceptance processes, and the documentation required to obtain agreement by the procuring activity that the acceptance criteria have been met.

The developer shall peer review test plans to ensure that the plans are complete, compliant with this standard, and clearly describe the test to be performed.

As a minimum, a test plan shall address the following:

1. Identification of test items, e.g., names, abbreviations and acronyms, version numbers, release numbers.
2. System overview (or reference) describing the system purpose, functions, operating sites, etc.
3. Overall test objectives and philosophy, testing strategy, and test objective/expected result for each item, including tailoring or interpretation of testing requirements.
4. Identification of separate test sites and environments (e.g., antenna pads, computer rooms) and the specification of environments and site requirements or constraints for each.
5. Required special test tools and equipment, simulators, facilities, interfaces, and any needed downtime of facilities and equipment.
6. Identification of required test personnel, organizations and the roles and responsibilities of each.
7. Planned tests and test levels and any dependencies on other tests.
8. Planned exceptions to testing in actual operational configurations and conditions and risk mitigation actions for those exceptions.
9. Collection or development of required test data, simulators, and test drivers. Identify the type and quantity of test data sets and justification of adequacy for the test purpose. Include the plan for validating simulators and test drivers prior to use in test.

10. Sequence of tests and schedules (or reference) for tests and all required test resources, e.g., procedures, data, simulators, tools, facilities, personnel, showing availability for preparation, start and duration of the tests.
11. Allocation of specification requirements to appropriate test and integration levels. Usually this is a reference to a requirements traceability matrix listing all design requirements and indicating a cross-reference to a verification method and the applicable test level.
12. Cecurity requirements for the test facility or location, if any.

4.3.2 Verification Methods

Assessment of each requirement and the design to meet the requirement shall be performed to determine the most effective verification method(s). The verification method(s) selected for each requirement shall be documented in a verification cross-reference matrix (VCRM), to be used in test procedure development. The four requirement verification methods, inspection, analysis, demonstration, and test, are defined in Section 3.

Tests shall be conducted using documented test procedures that include all of the required tests to fulfill with the test objectives in the approved test plans. The test objectives, testing criteria, and pass/fail criteria shall be stated clearly in the test procedures. The test procedures shall cover all operations in enough detail so that there is no doubt as to the execution of any step. Test objectives and criteria shall be stated to relate to design or operations specifications. Traceability shall be provided from the specifications or requirements to the test procedures in a VCRM.

The developer shall peer review test procedures to ensure that the procedures are complete, compliant with this standard, and clearly define the test steps to be performed.

Test procedures shall include a measurement tolerance for each measured parameter. The tolerance shall include a positive and negative uncertainty. Where practical, the individual procedure step that satisfies the requirement shall be identified. The test procedure for each item shall include, as a minimum, descriptions of the following:

1. Purpose, objectives, entry criteria, assumptions, and constraints, including which requirements are tested by specification identifier.
2. Test setup, identifying test articles by configuration identification, including software revision for software under test and supporting software such as operating system.
3. Initialization requirements.
4. Input data, including software configuration files, etc.
5. Test tools and test instrumentation.
6. Expected intermediate test results.
7. Requirements for recording output data.
8. Expected output data.
9. Minimum/maximum requirements for valid data to consider the test successful (at procedure step level, where appropriate).
10. Pass/fail criteria for evaluating results, including uncertainty constraints (at procedure step level, where appropriate).
11. Safety considerations and hazardous conditions.

4.4 Test Environments and Facilities

Test environments and facilities shall be equipped and configured to perform the tests described in the approved test plans and procedures. Test environments for each level of test shall be planned and developed to ensure capacity to support the expected usage during the test program. Capacity margin shall be adequate to maintain the test schedule, including dry runs, test run for record, retests, and regression tests. Test environment spares shall be sufficient for testing to proceed while failed equipment is replaced or repaired.

4.5 Test Instrument Accuracy and Calibration

Equipment and instruments used in tests shall be sufficiently accurate to measure within ±½ of the error interval specified for the measurand. Each instrument shall be used within the tolerances and the operating environment specified in the instrument specifications provided by the manufacturer. Instruments that require periodic recalibration shall have been recalibrated in accordance with the developer's metrology plan, but at no greater interval than recommended by the instrument manufacturer.

4.6 Documentation

Test plans, procedures, and the test documentation described below shall be collected and maintained in test documentation files. Developers shall maintain the test documentation files for the duration of development, operations and maintenance.

4.6.1 Test Configuration Audit

For each test execution, a test configuration audit shall be performed to document the versions and revision designators of all hardware, software, operating systems, configuration files and other items constituting the test environment. Test equipment used shall be listed with calibration dates and accuracy.

4.6.2 Test Data

Test data shall include the data required for preparation, simulation, or configuration, for performing the test, and data collected during and after the test. Test data shall be collected and maintained in a form to permit retest and the evaluation of performance under the various specified test conditions.

4.6.3 Test Log

Formal tests shall be documented in a test log. The test log shall identify the personnel involved and be time-tagged to permit a reconstruction of test events such as start time, stop time, anomalies, procedure steps changed or not completed, and any periods of interruption.

4.6.4 Test Discrepancies

Anomalies, discrepancies, and failures occurring during test activities shall be documented and dispositioned as specified in the developer's quality control plan. Test discrepancy and resolution records shall be reported to the procuring activity as required in applicable contract or development agreement. Discrepancy metrics must be collected and analyzed to assess testing effectiveness as described in Section 5.7.

4.6.5 Qualification and Acceptance Test Report

For qualification and acceptance tests, test results shall be documented in test reports. The test report shall state the degree of success in meeting the test objectives and shall document the details and conclusions from the test results (including verification status of each requirement), and a summary of the test results, deficiencies, problems encountered, and problem resolutions. The responsible developer design engineer shall certify the accuracy of the results.

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5. Detailed Requirements

Detailed requirements are provided for developmental tests and evaluation (DT&E) and operational tests and evaluation (OT&E). Developmental tests include tests performed during development of a ground system to support design and development, verify specification requirements and interface implementation, demonstrate acceptability of contract end items, and certify readiness for operational test by the procuring activity to validate the required capabilities of the system.

5.1 Development Tests

Development tests, including hardware parts, subassembly and unit, software unit, software component integration, and hardware/software integration testing shall be conducted to:

1. Validate new design concepts and alternative designs or the application of proven concepts and techniques to a new configuration.
2. Assist in the evolution of designs from the conceptual phase to the operational phase.
3. Verify that implemented software and assembled hardware is in accordance with the design.
4. Verify specification requirements are satisfied in the actual conditions of mission operations, exceptions documented and approved by the procuring activity.
5. Reduce the risk of committing designs to fabrication and production.
6. Validate design changes.
7. Develop and validate qualification and acceptance test procedures.
8. Investigate problems or concerns that arise after successful qualification.

Note: The amount and type of development testing depend upon the maturity of the subsystems and units used and the operational requirements of the specific program. An objective of development testing is to identify problems early in the design evolution so that any required corrective actions can be completed prior to starting formal qualification testing.

In addition to testing the functional, performance, accuracy and timeliness objectives of a design, development tests shall be performed to confirm manufacturability, compatibility with system safety, and nonfunctional quality attributes that are stated in the applicable specifications such as:

- Interoperability
- Reliability/Availability/Maintainability
- Scalability
- Testability
- Usability
- Supportability

System and information security requirements are included in functional requirements and tests shall be conducted to validate the design and implementation, plus any specified extra security test requirements, e.g., tests by security accreditation agencies.

Development tests to identify performance break points or margins beyond specification limits shall be performed if such tasks are defined in the SOW or special test requirements.

Ground hardware development tests may be conducted on breadboard equipment, prototype hardware, or representative operational equipment. Software development tests may be conducted in a software development environment or a software integration and test environment.

Development test procedures, input data, results, logs, required test metrics, deficiencies, and corrective actions shall be recorded in the Software Development File for software unit level tests, in Test Documentation Files for hardware and other software tests. Errors and defects discovered in development tests shall be documented and corrected in accordance with the developer's quality assurance procedures.

Development tests may be conducted at developer's in-plant test facilities, at a government-approved testbed, or at any other appropriate test facility. However, when performed at a government facility, that facility may require approval of the test plans and procedures. Internal developer documentation of development test plans, test procedures, and test results are normally used unless stated otherwise.

5.1.1 Hardware

Hardware development tests shall be performed to achieve the objectives listed above for antennas, RF subsystems, electronics, mechanical mechanisms, and related components.

Tests should be planned as progressive steps to identify problems early in design and assembly so corrective actions can be completed before starting formal qualification testing. Hardware development tests shall be performed at part, unit, the hardware integration levels (subassembly, subsystem, etc.), and hardware/software integration levels. In addition to development tests of functional and performance requirements, compliance with applicable site or facility installation requirements shall be verified.

5.1.1.1 Hardware Test Levels

Part, Material and Process Tests. These tests shall be conducted to qualify parts, materials, and processes to ensure proper application in the design, to ensure adequate performance margins, and to develop acceptance criteria for parts and material to avoid assembling defective hardware components. As a minimum, all new types of parts, materials, and processes are tested.

Subassembly and Unit Tests. Subassemblies and units shall be tested to demonstrate feasibility, minimize design risk, and evaluate design and manufacturing alternatives and tradeoffs required to best achieve the development objectives. Tests are also conducted to develop in-process manufacturing or assembly tests, inspections, and acceptance criteria for subassemblies and units to avoid assembling defective hardware components.

Subsystem Tests. Subsystem tests shall be conducted to evaluate components, demonstrate compliance of subsystem requirements flowed down to subsystem specifications from the system-level requirements, and provide baseline data on subsystem performance that allow trending and performance comparisons when system components are replaced and/or upgraded.

5.1.1.2 Environmental and Specialty Tests

Environmental and specialty tests shall be performed to verify the capability of hardware to operate reliably in the installed environment and perform required functions with safety for operating personnel.

Environmental Tests. These tests shall be conducted to verify that specified functional, performance, storage, and relocation requirements are satisfied. Hardware operated, stored, or relocated in

environmentally controlled environments can generally be verified by analysis and/or similarity. However, tests of hardware required to be used in one or more of the environmental conditions listed in this section shall be performed to verify compliance with functional and performance requirements. Similarly, if storage or transport is required in one or more of the environmental conditions listed, testing is required to demonstrate suitability for return to operations after being stored or relocated in those conditions. The environmental conditions are as follows:

- Hail
- Sand/blowing sand
- Dust
- Mud
- Salt fog
- Solar radiation
- Humidity
- Fungus growth
- Altitude
- Wind speed
- Snow and/or ice loading
- Temperature
- Chemical attack
- Thermal shock
- Handling shock/drop distance
- Electromagnetic pulse
- Immersion
- Vibration
- Explosive atmosphere
- Biological attack and/or infestation

Environmental testing shall be performed in accordance with MIL-STD-810 [2]. Testing for high-altitude electromagnetic pulse protection shall be performed in accordance with MIL-STD-188-125-1 [3] for fixed items and MIL-STD-188-125-2 [4]for non-fixed items.

Electromagnetic Compatibility (EMC) Tests. Ground hardware shall be verified to be compliant with FCC Class A requirements in Federal Code of Regulations FCC Part 15 [8] as a minimum. Verification may be by certification from equipment vendors. If a vendor does not certify compliance with FCC Class A requirements, or subsystem specifications have EMC requirements exceeding FCC Class A requirements, tests and measurements for verification shall be conducted in accordance with standards designated by the procuring activity or MIL-STD-461 [1].

Power Tests. For each subsystem, rack, or device that connects to the facility power infrastructure or is powered from an interfacing subsystem, power consumption and total harmonic distortion shall be measured at both peak load and nominal operating load. Measurements shall be performed in accordance with standards designated by the procuring activity or IEEE Standard 1100 [8].

Grounding and Bonding Tests. Grounding systems shall be tested for electrical resistance and continuity. Measurements shall be performed in accordance with standards designated by the procuring activity or IEEE Standard 1100 [8].

Fault Management and Built-in Test Equipment (BITE) Tests. Fault Management and BITE capabilities shall be demonstrated to verify identification of failures to a lowest-replaceable-unit level. BITE capability to resolve specified multiple system failures shall be demonstrated. Operation of BITE shall be demonstrated for both primary and redundant components. Failover to redundant components to recover from detected faults shall be demonstrated, and required failover time verified. Manual initiation of fault detection and isolation shall be demonstrated. The ability to select redundant components by command and restore system operation shall be demonstrated. BITE shall be verified at subsystem level, when possible, or at integrated system level if necessary to provide required configurations for test.

Dependability Tests. Verification of reliability, availability, and maintainability and integrity requirements shall be demonstrated. Demonstrations may be conducted over time periods shorter than those required and extrapolated to cover the required time period. Dependability testing shall be conducted using operational scenarios provided or approved by the procuring activity. Protection

from hazards designated by the procuring activity to personnel and to the system and the facility into which the hardware is to be incorporated shall be verified. Testing of RF exposure shall be performed in accordance with standards designated by the procuring activity or IEEE Standard C95[7].

Non-fixed Hardware—Unique Tests. Hardware for non-fixed systems will have additional requirements not associated with fixed-site systems. Unique tests and demonstrations required to verify these requirements may include, but not necessarily be limited to, the following:

1. Setup and teardown time with a specified number of people
2. Setup and teardown time in specific climatic environments
3. Transportability
    a. Compatibility with specific aircraft, ships, other vehicles
    b. Compatibility with railway transport in specific countries
    c. Compatibility with specific road conditions and speeds
4. Compatibility with cargo handling equipment and/or facilities
5. Permitted range of motion during operations
6. Operations in other than a horizontal position

Specialized fixtures, facilities and access to external equipment shall be identified in advanced test planning and coordinated with the procuring activity.

5.1.1.3 Commercial or Non-development Item (NDI) Hardware Test.

Testing of commercial or NDI hardware shall be conducted to verify that the function and performance of the item is as specified in vendor documentation and meets requirements for use in the current system design. These tests may be performed as part of a selection process or to verify functional capabilities and performance of an existing commercial or NDI item. Developer-selected acceptance tests shall be conducted on delivered items to ensure that they conform to the same specifications as those tested during the selection process. Tests of general-purpose computer hardware may be performed as unique hardware function and performance tests or in conjunction with tests of software executed on the computer. Required capabilities, characteristics or features not described in vendor-furnished documentation shall be tested as if the hardware is a developmental item.

5.1.2 Software

Software development tests shall be performed to achieve the objectives listed in Section 5.1 for software and firmware. Tests shall be planned as progressive steps to identify problems early in design and implementation so corrective actions can be completed before formal qualification testing is started.

Software development tests shall be performed at unit, unit integration, and hardware/software integration levels. Development tests for software include prototype tests, unit tests, COTS or reuse selection/verification tests, performance tests, integration tests, and interface tests. Software tests shall comply with test requirements in Software Development Standard for Space Systems [6].

5.1.3 Integration Test

Tests shall be performed to verify the integration of subsystems and operational hardware, correct implementation of interfaces, and error-free interaction between subsystems and between software

and hardware. These tests are performed in the development facilities, starting with earliest integration steps, whereas integrated system tests (see Section 5.4) are performed at operational sites or a designated operational testbed, after integration of the system under development is completed.

Unless exceptions are approved by the procuring activity, tests shall be performed with software and hardware of the system in operational configuration(s), including all reuse software and hardware, modified and unmodified, and COTS software and hardware. Approved exceptions are to be documented in the test report. As a minimum, integration test cases shall include testing:

1. Software-to-software, software-to-hardware, hardware-to-hardware interfaces, including limits and boundaries in interface control documents
2. Software and hardware functional and performance requirements allocated to the integrated system level
3. Integrated error and exception handling
4. System-level performance, such as acquisition and tracking, system throughput, timing, and accuracy requirements
5. Stress testing of worst-case scenario(s), data and transaction loads
6. Startup, termination, and restart (when applicable)
7. Fault detection, isolation and recovery handling (e.g., fault tolerance, failover to redundant units, BITE operation, failure data capture and reporting)
8. Resource utilization measurement (e.g., CPU, memory, storage, bandwidth)
9. Longevity and endurance tests (day/week-in-the-life) of sufficient length to demonstrate required stability and reliability

Note: Large ground systems consist of multiple architectural levels e.g., elements, or segments. Such systems may require multiple levels of integration tests. Strategy and planning for tests at multiple levels are to be described in the ground system integration plans.

5.2 Qualification Test

Qualification tests shall be performed to verify requirements allocated in ground system specifications. Tests shall be performed for requirements in hardware and software specifications in the ground system specification tree. Test procedures shall be developed for each test case indentified in the system verification test plan. Qualification tests shall be performed with approved test procedures and with hardware configurations and software versions identified, controlled, and installed by independent configuration management staff.

A test readiness review (TRR) shall be conducted prior to test execution to verify concurrence of required stakeholders that the test procedures, environment, equipment, and personnel are at a state of readiness so that the test objectives will be satisfied by the test. Dry run(s) of the tests shall be conducted to confirm that the procedures, equipment, and test environment are ready for successful formal run-for-record (RFR). If not, corrective actions shall be performed and test procedure updates made and dry runs repeated. Following the RFR, a test review board (TRB) shall be conducted to confirm that the test objectives were met, review test discrepancies, and identify any retest required. Test results shall be documented in a test report(s) and shall include a record of resolution of any test discrepancies. TRR, and TRB shall be conducted in accordance with the technical review and audit standard specified by the procuring activity.

Hardware. Hardware qualification tests shall be performed to verify requirements allocated to hardware unit and subsystem specifications as well as to ensure that subsequent items produced and assembled from the same design meet the same requirements as the qualification-tested items.

Hardware with multiple items from the same design may be qualification tested using protoqualification methods, i.e., a first article is tested to full specification levels plus a margin to ensure compliance given expected variation in manufacturing and assembly of subsequent items. Subsequent hardware items can then be qualified by similarity.

Assessment of first article manufacturing/assembly shall be performed to identify potential manufacturing or workmanship issues that would result in noncompliance in subsequent items. These issues shall be assessed in acceptance tests and inspections for each item. In production, random testing and inspection shall be performed to provide assurance of compliance.

COTS hardware operating within the vendor-specified operating range shall be qualification tested for functional and performance requirements. Compliance with environmental requirements may be verified by analysis.

General purpose computers may be qualification tested in conjunction with software qualification tests.

Hardware with embedded software/firmware shall be qualification tested following qualification of the software/firmware unless the hardware/software architecture requires test as an integrated entity.

Software. Software qualification tests shall be performed to verify requirements allocated to software requirements specifications and software interface specifications. Software qualification tests shall comply with test requirements in Software Development Standard for Space Systems [6].

Ground System. Qualification tests shall be performed to verify ground system specification requirements. The tests shall be performed in actual operational configurations and conditions to verify compliance with specifications as the system will be used in mission operations. Exceptions and risk mitigation shall be approved by the procuring activity. These tests may be designated as acceptance tests in lieu of separate acceptance tests, as determined by the procuring activity (see Section 5.3). Ground system requirements that are completely allocated to a single lower-level specification may be considered verified in the qualification test for that lower-level specification and need not be reverified at system level. Requirements that are partitioned and allocated to multiple lower-level specifications shall be verified in system qualification tests. Rationale for qualification at lower level shall be described in appropriate test plans and indicated in the VCRM.

Large ground systems that have multiple architectural levels, e.g., elements or segments, will have multiple levels of qualification tests. Strategy and planning for tests at multiple levels, and interrelationships of the tests, shall be described in the ground system test plans. Allocation of requirements to test levels shall be documented in the VCRM.

5.3 Acceptance Test

Acceptance tests shall be conducted to demonstrate the acceptability of each deliverable item to meet specification requirements and to demonstrate error-free workmanship in manufacturing and assembly. Acceptance tests may be unique tests or a subset of qualification tests. The acceptance tests and the procedures for the acceptance tests shall be approved by the procuring activity. Acceptance tests may be performed by the developer or an independent organization as designated by the procuring activity. The scope, organization, roles, responsibilities, sequence, and location of acceptance tests shall be as described in the acceptance test plan.

The acceptance test hardware and software baseline shall include in the final operational configuration all development items, NDI, GFP, and COTS hardware and software. Factory acceptance test (FAT) shall be performed to verify all system requirements, if possible. Requirements that require site configuration or environments to verify shall be tested during site acceptance tests or unique tests to verify those specific requirements.

Site acceptance tests (SAT) shall be performed by the developer in accordance with site-approved procedures to verify compliance of the system with site installation requirements and ensure that integration of the delivered system into the site configuration will cause no disruption to operations. Site installation tests shall be performed by the developer prior to SAT to verify integrity of hardware following transportation and installation, and to verify software compatibility with site network and other interface configurations. Site installation tests may be selected factory tests or unique tests designed to adequately confirm readiness for site acceptance tests, integrated system tests, and operational tests.

The TRR, dry run(s), RFR, and TRB shall be conducted and test report(s) prepared as described in Section 5.2, Qualification Test. A designated representative of the procuring activity will be present at TRR, RFR, and TRB.

Acceptance test results shall be documented as required in the acceptance plan for use in the physical configuration audit (PCA) and system verification review (SVR) or functional configuration audit (FCA).

5.4 Integrated System Tests

Integrated system tests shall be performed to exercise, to the maximum extent that is practical and possible, the system in development plus all systems that interface and interoperate with that system. Unless exceptions are approved by the procuring activity, integrated system tests shall be performed on the integrated hardware and software items installed in an operational system with connection to actual interfaces, and these tests shall be conducted at the target site with the support of the operational personnel.

The objective of the tests is to ensure that the products, even if from multiple developers, function correctly when integrated, that interfaces are verified, and that all system requirements or specifications are met. Tests shall be designed to use actual mission operations configurations and conditions to the maximum practical extent. End-to-end tests shall be performed that exercise the full operational configuration, including space vehicle, with operational timelines and data loads. External systems that could affect the operation of system(s) in test, e.g., RF emitters, shall be operated or simulated to replicate conditions expected during operations. Test articles, configurations and conditions that differ from the operational configuration shall be identified in test planning and risk mitigation described.

A development test bed approved by the procuring activity as sufficiently simulating the operational system capability for test purposes may be used for integrated system tests if target sites, operational complexes, or other suitable operational support areas are not available.

The integrated system tests shall incorporate tests of the affected interfaces of the ground equipment and software with other elements of the operational system. The tests shall be structured as appropriate to demonstrate design requirements of the system related to such items as performance, electromagnetic compatibility, reliability, maintainability, system safety (e.g., hazardous noise, radiation hazards, pressure vessels), logistics supportability, operational procedures, and personnel performance.

The tests shall demonstrate the following, as applicable to the installation, modification, or upgrade:

1. reliable operation is achieved at specified design limits.
2. system functional and performance requirements are met.
3. the system can recover from hardware or software malfunctions within the specified time without loss of data or control.
4. performance requirements are met under all required logical or physical device assignment combinations.
5. software and hardware modifications or upgrades have not degraded the capability of the system's baseline or of other operational systems.
6. security mechanisms are in place or incorporated to protect resources from unauthorized access or break-in.

Tests are to be focused on the external interfaces involved, the use of operational databases and operational scenarios, and the system requirements from a mission operations perspective.

The tests shall include other applicable tests, such as:

1. A reliability demonstration
2. A maintainability demonstration
3. System safety tests, inspections, and evaluations in such areas as hardware inspections for electrical and mechanical hazards, including caution labeling
4. Evaluation of the fire suppression system
5. Evaluation of emergency systems
6. Use of hazardous materials
7. Possibility of personnel exposure to any equipment and conditions considered hazardous
8. RF radiation testing to determine actual levels of radiation to which personnel may be exposed and to evaluate the accuracy of the mathematical predictions of radiation levels
9. Proper functioning of any radiation warning systems
10. Proper procedures for inspection, operation, and maintenance of pressure vessels

The TRR, dry run(s), RFR, and TRB shall be conducted and test report(s) prepared as described in Section 5.2, Qualification Test. A designated representative of the procuring activity shall be present at TRR, RFR and TRB.

5.5 Operational Tests

Operational tests are planned and conducted by the procuring activity test organization (or an independent test organization designated by the procuring activity), in coordination with the operating organization. The test organization is responsible for the development of test plans, test tools, and test procedures, the conduct of the test, and preparation of test reports. Developers shall provide support for the tests and the resolution of deficiencies within the scope of the applicable contract or development agreement and as directed by the procuring activity. Support by developers includes collaboration with the procuring activity test team, the operating organization and independent test groups to conduct test planning, coordinate and align DT&E and OT&E objectives, and identify potential combined developmental and operational tests.

5.6 Retest and Regression Tests

5.6.1 Retest

When previously tested hardware parts/components or software is changed, the hardware and software shall be retested. Retesting may also be necessary if a discrepancy occurs while performing required testing. Limited retesting may be adequate to verify that the change is satisfactory and no new problems have been introduced. However, the extent of retest shall be determined by evaluation of the failure analysis, cause of the failure, and extent of the changes.

Retest During Qualification/Acceptance Testing. If a test discrepancy occurs during qualification or acceptance testing, the test may be continued without corrective action if the discrepancy does not affect the validity of test data obtained by the continuation of testing. Otherwise, the test shall be interrupted, the cause of the discrepancy determined, and corrective action completed before testing is resumed. If the discrepancy is caused by the test setup, test software, or a failure in the test equipment, the test being conducted at the time of the failure may be continued after the cause is removed and corrected as long as the failure did not overstress the item under test. Retesting may be required to establish a basis for determining compliance of a test item to a specification or requirement, and may be required to assess the readiness of test items for subsequent testing.

Retest During Operational Testing. If a discrepancy occurs during operational testing, the test director designated by the procuring activity shall be responsible for assessing the effect of the discrepancy to determine whether the discrepancy has jeopardized the probable success of the remainder of the test. The test director may decide to continue, or halt the test and conduct a subsequent retest. Developers shall provide support for resolution of deficiencies and subsequent retest within the scope of the applicable contract or development agreement and as directed by the procuring activity.

5.6.2 Software Regression Test

To identify unexpected side effects of software changes, software shall be regression tested in addition to tests of the specific changes. Regression tests shall be performed (1) after changes to previously tested software, and (2) after installation of modified software in new environments, e.g., new test environments, site reinstallation, new sites. Software regression tests shall comply with test requirements in Software Development Standard for Space Systems [6].

The scope of regression tests shall be determined by analysis of the type and extent of the changes. The rationale for selection and scope of regression tests shall be documented in test documentation files. Considerations for the extent of regression test include the structure of the software (tightly or loosely coupled), criticality of the software to operations, complexity of functionality, complexity of interfaces, and extent of the modifications if changing a mature system.

Regression tests may be selected subsets of previous compliance tests or unique tests designed to probe for unexpected side effects of changes or installation in new environments, e.g., standard regression tests run on a software component after any change, or installation checkout tests.

5.7 Test Discrepancy Management and Reporting

Testing of complex ground system hardware and software can result in a large numbers of discrepancy reports, requiring disciplined tracking and management to closure and accounting of the disposition of each discrepancy. Each test discrepancy shall be recorded in a discrepancy report (DR) and corrective actions are to be documented. Anomalous behavior observed in non-test operation of the system, such as demonstrations, rehearsals, etc., shall be recorded and resolved in the same

manner as test discrepancies. Each discrepancy report shall include, minimally, a description of the problem, its severity (to the granularity specified by the procuring activity), an assignee, the corrective action, system components modified, and effort required for correction. The developer shall provide reports of discrepancies and corrective actions to the procurement activity in accordance with contract requirements or development agreements.

Metrics on DRs shall be collected and used to assess test program progress and effectiveness, measure trends, provide measures of defect levels and manage the progress of discrepancy resolution. The specific metrics, collection and reporting frequency, and analysis required shall be as specified in the metrics plan approved by the procuring activity.

5.8 Tests During Sustainment Phase

5.8.1 Hardware

During sustainment, two types of hardware testing are required. Maintenance tests shall be performed at routine, scheduled maintenance intervals to verify that hardware performance is maintained. In addition, tests shall be performed to demonstrate that performance capabilities are maintained after hardware replacements are made. For both types of sustainment tests, subsets of the overall system-level testing shall be performed to demonstrate end-to-end performance.

Replacement units shall undergo the same testing at a unit and subsystem level as required during qualification:

1. Interface requirements for the replacement items shall be verified
2. End-to-end subsystem tests such as bit error rate (BER) shall be performed
3. BITE functionality, if present, of the replacement units shall be demonstrated

5.8.2 Software

Software tests during sustainment shall be conducted in accordance with the test requirements listed above for development. Unit tests shall be conducted for all units with modified software. Integration, subsystem qualification, regression and acceptance tests may be selected subsets of previous tests plus new tests based on the extent of the required modifications. A test designed to demonstrate that a defect has been corrected must be demonstrated to fail when executed on the software without the correction.

5.8.3 System Tests

A minimum suite of integrated system tests and system-level regression tests shall be established, to be performed following any sustainment modifications to the ground system. In addition, each modification during sustainment shall be assessed to determine if additional unique tests are to be performed to validate ground system readiness for return to operations. A test designed to demonstrate that a system failure has been corrected must be demonstrated to fail when executed on the system without the correction.

6. Notes

This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.

6.1 Data Item Descriptions (DIDs)

Test-related DIDs:

Acceptance Test Plan	DI-QCIC-80553
Electromagnetic Interference Test Procedures	DI-EMCS-80201
Electromagnetic Interference Test Report	DI-EMCS-80200
Reliability Test Procedures	DI-RELI-80251
Reliability Test Reports	DI-TMSS-81586
Software Test Description	DI-IPSC-81439
Software Test Plan	DI-IPSC-81438
Software Test Report	DI-IPSC-81440
Test Plan	DI-NDTI-80566
Test Procedure	DI-NDTI-80603
Test/Inspection Report	DI-NDTI-80809
Test Plans and Procedures	DI-SESS-81704

Current versions of these DIDs can be found at the Acquisition Streamlining and Standardization Information System (ASSIST) website: https://assist.daps.dla.mil/quicksearch/

6.2 Acronym List

BER	Bit error rate
BITE	Built-in test equipment
COTS	Commercial-off-the-shelf
CPU	Central processing unit
DID	Data item description
DOD	Department of Defense
DR	Discrepancy or deficiency report
DT&E	Development test and evaluation
EMC	Electromagnetic compatibility
FAT	Factory acceptance test
FCA	Functional configuration audit
FCC	Federal Communications Commission
GFP	Government-furnished property
IV&V	Independent verification and validation
NDI	Non-developmental item
OT&E	Operational test and evaluation
PCA	Physical configuration audit
RF	Radio frequency
RFR	Run for record
SAT	Site acceptance test
SDF	Software development folder, or file

SOW	Statement of work
SVR	System verification review
TDF	Test development folder
THD	Total harmonic distortion
TRB	Test review board
TRR	Test readiness review
VCRM	Verification cross-reference matrix

SMC Standard Improvement Proposal

INSTRUCTIONS

1. Complete blocks 4 through 7. All blocks must be completed.
2. Send to the Preparing Activity specified in block 8.

NOTE: Do not use this form to request copies of documents, or to request waivers, or clarification of requirements on current contracts. Comments submitted on this form do not constitute or imply authorization to waive any portion of the referenced document(s) or to amend contractual requirements. Comments submitted on this form do not constitute a commitment by the Preparing Activity to implement the suggestion; the Preparing Authority will coordinate a review of the comment and provide disposition to the comment submitter specified in Block 6.

SMC STANDARD CHANGE RECOMMENDATION:	**1. Document Number** SMC-S-024	**2. Document Date** 2013

3. Document Title	Test Requirements For Ground Systems

4. Nature of Change
(Identify paragraph number; include proposed revision language and supporting data. Attach extra sheets as needed.)

5. Reason for Recommendation

6. Submitter Information

a. Name	**b. Organization**
c. Address	**d. Telephone**
e. E-mail address	**7. Date Submitted**

8. Preparing Activity

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